FIRE HISTORY OF A FOREST, SAVANNA, AND FEN MOSAIC AT WHITE RANCH STATE FOREST

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Abstract—We present the fire history of a 1-km^2 area that is a mosaic of oak forest, savanna, and fen on the White Ranch State Forest, Howell County, Missouri. We dated 135 fire scars on 35 cross-sections of post oak (*Quercus stellata*) trees and constructed a fire chronology dating from 1705 to 1997. Mean fire return intervals by periods were 3.7 years (1705 to 1830), 7.6 years (1831 to 1960), and 3.6 years (1961 to 1997). Fire frequency was positively correlated (r = 0.53, p <0.01) with the expansion and migration of the Osage Tribe from 1710 to 1830. Later, between 1831 and 1900, exponential increases in Euro-American population density were negatively correlated (r = -0.64, p <0.05) with fire frequency. Fires were more likely to have occurred in drought years before 1830 than after 1830. Droughts after 1830 were related to the percent of trees scarred during years with evidence of fire.

INTRODUCTION

Wildfires have influenced Ozark forests, prairies, and wildlife for centuries (Chandler and others 1983). Speculation on the fire history of many areas in the southwestern Ozarks has been difficult because of the anthropogenic influence (Westin 1992) on these fire regimes and the highly variable nature of fuels and vegetation. Knowledge of fire history provides an ecological basis for restoring fire disturbance and developing silvicultural prescriptions that use fire to favor native communities. The objective of this study is to document a fire regime in a landscape with the potential for diverse vegetative assemblages, both in time and space, which includes closed canopy oak forests, savannas, prairies, and fens. We present a 292-year fire history based on dendrochronological analyses of fire scars for a site near the West Fork of the Spring River on the White Ranch State Forest, Howell County, Missouri.

METHODS

The study area is located (36° 32′ N, 91° 52′ W) along the northeastern slopes of the West Fork of the Spring River in the White Ranch State Forest, which is managed by the Missouri Department of Conservation. The landscape in the area is gently rolling with about 37 m of elevation change per km. The study site is about 1 km^2 in area and is presently covered by a complex mosaic of oak forests in the uplands and slopes, savannas and glades along slopes, and grassy fens in low lands.

Cross-sections were cut within 20 cm of ground level from 44 post oaks in the study area. Trees with solid boles were selected for cutting by sounding with a long handled ball pin hammer. The majority of the post oaks at the study site were hollow. Of the 44 trees cut only 35 cross-sections were used in identifying fire scar years. Nine trees sampled were deleted from analysis because heart rot, indistinct rings, or injury made precise dating of fire scars impossible. Trees ranged in age from 12 to 300 years or more.

Fire scars in this study are defined as basal injuries, which have killed cambial cells, exhibit a localized cambial growth response, and contain callus tissue. Fire scars also are associated with abnormal tyloses formation, general growth responses (from release or crown damage), and false rings. Often there was no external evidence that a post oak tree had a fire scar, although there were many hollow trees with external fire scars in the surrounding area.

Many other types of scars were present on the cross-sections. Damage caused by pin worms and bark scarrers was not common but it was distinctive and not easily confused with fire scars. Lightning scars were identified by their presence in sections well above the ground.

Fire wounds from ground level sections of post oak were used to reconstruct fire frequency. All fire dates were designated as the year of growth response to the injury. Thus, a scar that we dated to 1770 may have been caused by a fire that occurred anytime in the previous dormant season, approximately September 1769 to April 1770. This is of particular importance when considering if fires occur more frequently during drought years as indicated by ring width.

Dendrochronology uses the pattern in tree-rings caused by climate to date annual growth increments (Stokes and Smiley 1968). This enables accuracy in dating to the year, serves as a check on ring counts from live trees, and allows for the dating of wood of unknown age. Post oaks in this study were dated using a post oak chronology from Clayton Ridge (Stahle and others 1985) on the Rolla-Houston Ranger District of the Mark Twain National Forest. Annual rings were dated using skeleton plots of ring-widths, measured ring-width series, signature years, and ring counts.

Post oak is probably the most fire resistant species in the Ozarks, with the possible exception of shortleaf pine. The determination of fire frequency is difficult using post oak

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because this species is very resistant to scarring by low intensity fires. Paulsell (1957) noted that only 10 percent of the post oaks were scarred in annually burned plots, whereas 23 percent of the post oaks were scarred in the periodic burn plots. On the periodically burned plots, litter build up may have resulted in greater fire intensities that were capable of scarring more trees. This relationship between fuel buildup, fire intensity, and ability to scar trees may result in an under estimate of the number of fires in post oaks growing under low intensity surface fire regimes. More important, however, is the under estimation of fire frequency due to scarring resistance in post oak. For example, only one scar may be produced for every four to ten exposures to low intensity fires. Thus, mean fire intervals determined from fire scars on oak trees should be viewed as minimum fire return intervals.

We also attempted to sample trees in various size classes to minimize the effect that tree size has on scarring and to increase the accuracy of the composite fire chronology. Further, we constructed a composite fire scar chronology (Stokes and Dieterich 1980) from all of the 135 fire scars identified on the 35 dated cross-sections. Percent of trees scarred in any given fire year was determined by dividing the number of sample trees with ring records in a fire year by the number of trees with scars and multiplying by 100.

RESULTS AND DISCUSSION

Fire Frequency

A fire scar chronology composed of all the fire scars from the sample of 35 post oaks dated is given in figure 1. The frequency of fire, as mean fire return intervals (MFI), is summarized for various historic or cultural periods over the last 292 years in the 1-km^2 study area in table 1. The mean fire return interval was similar for the Native American Period (1711 to 1830) and the Modern Period (1961 to 1997), but the fire scar record indicates that fires burned less frequently during Euro-American settlement and development (1831 to 1960). The percent of trees scarred was significantly different ($t=5.1$, $p<0.0001$) for the two periods, 1711 to 1830 and 1831 to 1960. The mean percent of trees scarred during the Native American and Modern Periods was four to six times that of the period of Euro-American settlement and development (table 1). Fire frequency and percent of trees scarred were not significantly different ($t=1.78, p=0.08$) between the two periods, 1711 to 1830 and 1961 to 1997 because of the high variance and short duration of the Modern period. However, there certainly could be significant ecological differences resulting from fires during these two periods. Mean fire return intervals (MFI) at White Ranch State Forest are similar to those at three other study sites (table 2) that also have oak forest and savanna vegetation (Guyette and Cutter 1991; Cutter and Guyette 1994; Guyette and McGinnes 1982) in the Missouri Ozarks.

Table 1—Mean fire return intervals by historic periods

Historic period	MFI	Range	Trees scarred (percent) All years	Trees scarred (percent) Scar years
	- - *years* - -			
Native American (1711–1830)	3.7	1 – 13	4.3^{a}	17.5^{a}
Euro-American settlement (1831–1960)	7.6	2 – 17	0.7^{b}	5.6^{b}
Modern agriculture (1961–97)	3.6	1 – 7	3.4^{ab}	12.8^{ab}
All periods (1711–1997)	4.9	1 – 17	2.6	13.2

Mean fire return intervals (MFI) are for the presence of fire (a fire scar on at least 1 of 35 samples) in all or part of the 1-km^2 study area.
Statistics with the same superscript letters on different lines are not significantly different ($\alpha = 0.05$).

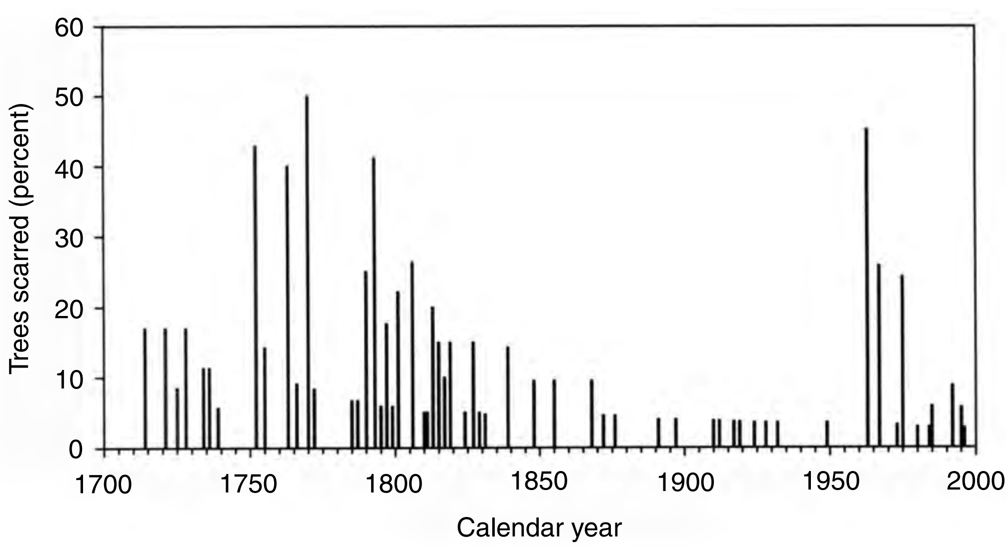

Figure 1—Composite fire scar chronology and percent of trees scarred by fire year for the study site at White Ranch State Forest, Howell County, MO.

Table 2—A comparison of mean fire return intervals at White Ranch State Forest, Caney Mountain Wildlife Refuge, Laclede County, and Cedar Glades

Period	WRSF	CMWR	LACCO	CEDAR
	- - - - - - - - - - - -	*years*	- - - - - - - - - - - -	
1710–1830	3.7	4.8	3.0	3.3
1831–1980	7.6	6.9	12.5	9.4

WRSF = White Ranch State Forest; CMWR = Caney Mountain Wildlife Refuge; LACCO = Laclede County; CEDAR = Cedar Glades.
All sites are more than 50 km from the White Ranch State Forest.

Climate, Fire Occurrence, and Fire Severity

The mean reconstructed Palmer Hydrologic Drought Index (Cleaveland and Stahle 1996) for all fire years before 1830 was -0.66 compared to a mean of +0.32 for all fire years after 1830 (table 3). Before 1830, drought was an important factor in the occurrence of fire years, but after 1830 fires burned in years of above average precipitation. This may be because drought increased the probability of fires spreading to the study site or because Native Americans chose the most severe fire weather to ignite fires. Both factors probably contributed to the occurrence of fires in years of growing season drought before 1830. Others (e.g., Sutherland 1997) have noted the general lack of correspondence between fire years with drought years after 1830.

When the percent of trees scarred is calculated based on those years with evidence of fire, there is no significant correlation between growing season drought and the percent of trees scarred before 1830, but there is a significant correlation ($r = -0.47$, $p = 0.01$) between growing season drought and the percent of trees scarred after 1830. This indicates that before 1830 growing season droughts had more of an effect on the year of occurrence of a fire and little effect on the severity of fire at the study site. The opposite relationship occurs after 1830 when growing season drought does not affect the year of occurrence of fire but is related to the severity (percent of trees scarred) of fire.

Cultural Interpretations

In 1818, Schoolcraft (1821) observed several abandoned "Indian camps" just below the confluence of Bryant Creek and the North Fork of the White River. These camps were west of the study site separated by 40 km of gently rolling terrain. The study site also lies near the confluence of two streams, the West and South Forks of the Spring River. Schoolcraft also commented on the abundance of bear, elk, deer, and beaver in the area. Thus, geographic location at the confluence of rivers, the distance from sites of known Native American occupation, and the abundance of game suggests that there was reason for a human population within the vicinity of the study site before Euro-American settlement of the area.

Population, Land Use, and Fire

Population and agriculture are two factors that greatly affect anthropogenic fire regimes. Fire history at the White Ranch State Forest shows a changing relationship to these important factors. Fire frequency at the study site was positively correlated ($r=0.53$, $p <0.01$) with the expansion (Wiegers 1985) and migration (Wolferman 1997) of the Osage Tribe (Marriott 1974) between 1710 to 1830 (table 4). During the latter part of this period, Shawnee, Delaware, and Cherokee were migrating through the area (Weslager 1978) and they may have contributed to the frequency of fire at the study site. A positive relationship between fire frequency and human population makes sense (Guyette and Cutter 1997) because more people usually cause more ignitions, especially at low levels of human population density. In contrast, exponential increases in Euro-American population density between 1830 and 1900 were negatively correlated ($r = -0.63$, $p <0.05$) with the scarring of trees. How human population density during this period (1830 to 1900) affected the frequency of fire is not well understood and is addressed in the next section.

Population density is not significantly correlated with the percent of trees scarred during the 1900s. This relationship is expected as population density increases because a complex of cultural factors controls the frequency of fire. Anthropogenic fire is affected by changes in land use, in the type of ownership, in the price of timber and the price of beef, the value of real estate, and by the adoption of fire suppression policies. Since 1960, there has been a

Table 3—Drought and the percent of trees scarred by historic period

Period	PHDI	%TREE X PHDI	PHDI (%TREE > 6)
Native American (1711–1830)	-0.66 (n = 31)	r = -0.47 (p = 0.01)	-0.97 (n = 24)
Euro-American (1831–1997)	+0.32 (n = 24)	r = +0.04 (p = 0.80)	-1.22 (n = 7)

%TREE = percent of trees scarred; PHDI = Palmer Hydrologic Drought Index. Negative values of the reconstructed Palmer Hydrologic Drought Index represent relatively dry periods (Cleavland and Stahle 1996). Correlations are given for the percent of trees scarred and the PHDI (%TREE X PHDI). The PHDI is also given for only those years with multiple scarring of trees (percent trees scarred > 6).

Table 4—Correlations among population density, cattle density, and the percent of trees scarred (an 11-year moving average) by periods

	1711–1830	1830–1900	1900–97	1960–90
Human population density	0.53	-0.63	0.08	-0.73
Cattle on farms	—	-0.52	0.07	-0.74

Cattle data and the correlation for the 1830 to 1900 period are based on the State cattle population from 1867 to 1900. Positive and negative correlations indicate that trends in the percent of trees scarred are coincident with changes in human and cattle production.

decrease in the percent of trees scarred and an increase human population density. The number of cattle on farms follows the same general trends as human population and its correlation with the percent of trees scarred (table 4).

Trends in the Fire Frequency of Forests and Savannas

The trends in fire scarring of trees at the White Ranch State Forest are similar to patterns observed at other fire history sites in oak forest-savanna mosaics in southwestern Missouri (fig. 2). These sites include a site in the redcedar glades in Douglas County (Guyette and McGinnes 1982), a site on an oak-hickory ridge near the Gasconade River in Laclede County, (Cutter and Guyette 1994), and a site in a post oak forest-savanna at the Caney Mountain Wildlife Refuge (Guyette and Cutter 1991). The trend at these sites has been an increase in fire frequency before 1780, an increase in fire frequency and the percent of trees scarred between 1780 and 1820, and then a steady decline in fire frequency ending circa 1900. A notable exception in fire trends at White Ranch State Forest is that the frequency of fire increases between 1960 and 1997, and it is greater than at the other sites, although differences are not statistically significant.

Differences in the fire regime before and after 1830 may be due to both a change in the frequency of fire and a change in the intensity of fire. The difference in the percent of trees scarred between the Native American period and the period of Euro-American settlement and development could be the result of a number of factors (table 5) that reduced the scarring of trees. These might include changes in fuel continuity, in vegetation type, in fuel characteristics, in farming practices, in the density of large herbivores, in fire frequency, and in the frequency and seasonality of human ignitions.

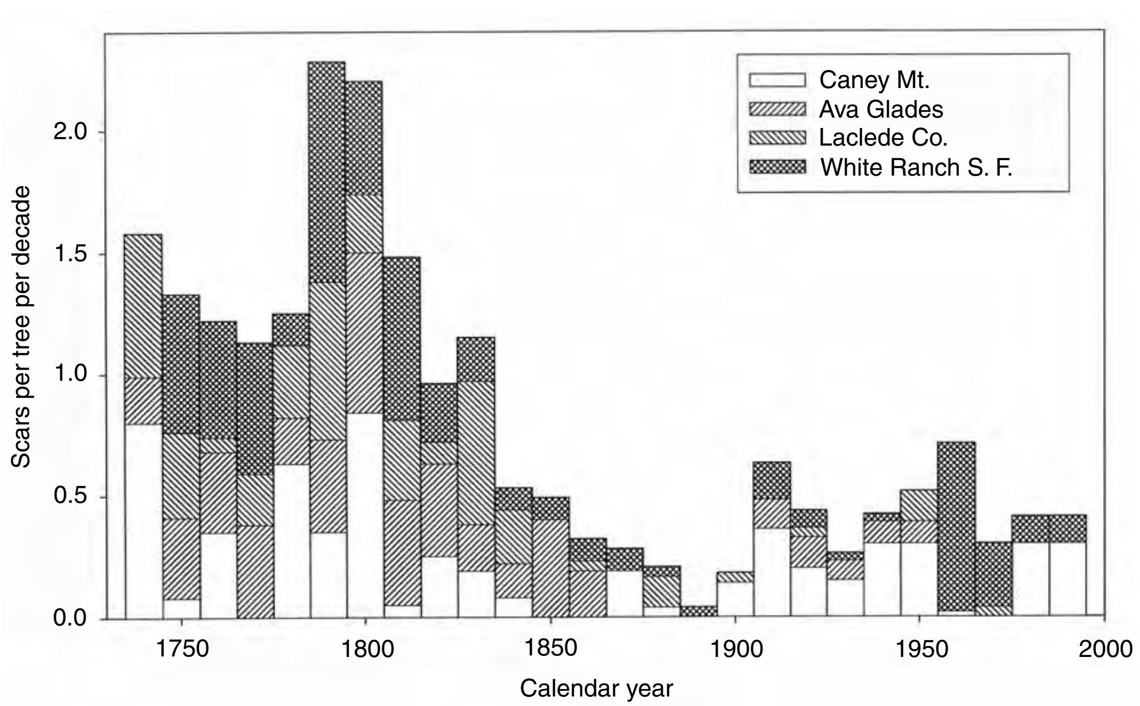

Figure 2—Patterns in fire scarring of post oaks at White Ranch State Forest compared with other fire history sites from oak forests and savannas throughout the Ozark Highlands in Missouri.

Table 5—Possible factors influencing fire frequency and the scarring of trees before and after 1830 in forest-savanna vegetation of the southwestern Ozarks

Before 1830	
1	Fuel buildup during fire free intervals facilitates fire spread and intensity
2	Fires in late summer and fall of year burn hotter than spring fires
3	Warm season grasses create more volatile fuels
4	Effects on fuels by herbivores limited
5	Few firebreaks facilitate continuous spread of fire
6	Native Americans choose the most severe fire weather for burning
After 1830	
1	Fire intensity low from annual fuel reduction by fire
2	Fires in spring cooler than fall fires
3	More cool-season grasses are less volatile
4	Fuel reduction and trampling by more large herbivores
5	Increasing numbers of firebreaks, roads, and fields
6	Fine prairie fuels replaced by slower burning forest litter

Post Oak Regeneration

The year of growth initiation for each post oak stem was determined. No periods of regeneration stood out as exceptional or different from the rest. This is in contrast to an earlier study (Cutter and Guyette 1994) in which the trees sampled indicated that the dominant overstory trees had regenerated in a stand replacement event that resulted in an even-aged overstory. Of the post oaks sampled, none had pith dates (no stems regenerated) between 1815 and 1880, which can be characterized as a period of decline in fire frequency, in percent of trees scarred in a fire year, and in increased settlement and agricultural development. However, because the sample trees were not randomly selected, any inferences regarding stem initiation may give a biased view of oak regeneration in relation to fire disturbance.

CONCLUSIONS

1. Mean fire return intervals by periods were 3.7 years (1705 to 1830), 7.6 years (1831 to 1960), and 3.6 years (1961 to 1997). The percent of trees scarred is significantly different ($t=5.1$, $p < 0.0001$) for the two periods 1705 to 1830 and 1831 to 1960. Since some fires may not have scarred any of the sample trees, these interval estimates are minimum fire return intervals for the study area.

2. Population density is an important factor related to fire frequency. Before 1830 fire frequency is positively related to human population density, a source of anthropogenic ignitions.

3. Later (1830 to 1900) population density is inversely correlated with fire frequency as land use effects reduce the frequency and severity of fires.

4. Fires were more likely to have occurred in drought years before 1830 than after 1830.

5. Droughts are related to the percent of trees scarred after 1830 in years with evidence of fire.

6. Historical documentation of Native American populations 40 km west of the study site in the early 1800s indicates anthropogenic ignitions maintained the level of fire frequency documented before 1830.

7. The trends in fire frequency at White Ranch State Forest are similar to those found at three other sites in the Missouri Ozarks with areas of oak forest and savanna vegetation.

8. A declining trend in the percent of trees scarred at White Ranch State Forest between 1830 and 1900 is the opposite of trends of increasing fire frequency found in highly dissected and forested regions of the Ozarks such as the Current River watershed.

9. Although a complete age structure was not determined for the study forest, dates of stem initiation of the dominant post oaks sampled do not indicate that this was an even-aged forest originating from a stand replacement type disturbance. Dominant post oaks regenerated throughout the past 292 years resulting in an irregular age structure of overstory oaks. Regeneration of dominant post oaks was minimal during a period in the fire chronology when fires burned less frequently and with less intensity.

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